Preliminary Findings
Arkansas River Water Needs Assessment

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Foreword

The purpose of this paper is to summarize all the information and findings associated with Arkansas River Flow Needs Assessment. This presentation will:

(1) introduce the reader to the study setting and study methodology

(2) summarize the legal and institutional context that river managers must work within in order to implement river management improvements that could benefit both natural resources and water users.

(3) summarize how flows in the upper basin have changed as a result of increasingly intensive management of water from the late 1800's to the present.

(4) provide a summary of how the Fryingpan-Arkansas Project is operated to meet the needs of water users

(5) summarize resource values and their corresponding flow needs for the Arkansas River and four reservoirs - Pueblo Reservoir, Twin Lakes, Turquoise Reservoir, and Clear Creek Reservoir.

This document is organized into four parts:

Section I summarize the physical setting for the study, the purpose of the study, the existing land and water management framework, and the methodology used in the study.

Section II is a summary of the major legal and institutional elements involved in Arkansas River management, with emphasis on the major facilities and laws that impact flows on the main stem upstream from Pueblo Reservoir.

Section III provides a summary of an extensive hydrologic analysis that was performed to determine how construction of water management features, such as transbasin import systems and large storage facilities, have affected the magnitude and timing of river flows.

Section IV explains how the how the Fryingpan-Arkansas Project is operated if the sole objective is to maximize the yield of water from the project for human uses. An annual hydrograph for this operational approach is presented, using data from the 1982 to 1995 period. This hydrograph provides a baseline against which natural resource needs can be compared.

Section V incorporates numerous tables that allow the reader to see at a glance the flows required to support natural resource values on the Arkansas River, at Turquoise Lake and Twin Lakes, and at Pueblo Reservoir. This is followed by a discussion of the key findings and conclusions reached about the individual resource values analyzed during the assessment.

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I. Introduction to the Water Needs Assessment

The Arkansas River and its related reservoirs between Leadville and Pueblo are an important hydrological, biological and recreational resource. Competing demands for water have made it necessary for management agencies to thoroughly understand affects to various resources and carefully weigh the user preferences, environmental requirements, and legal and administrative constraints associated with decisions that affect water uses, stream flow, and reservoir levels. The Water Needs Assessment is intended to provide critical data that managers and the public must be aware of in order to better understand the issues before they commence decision making processes and form opinions.

A. Physical Setting

The Arkansas River is the major drainage system in southeastern Colorado. Its headwaters are located in the Sawatch and Mosquito Ranges near Leadville, and Sangre de Cristo Mountains between Salida and Canon City. In the upper basin, within Lake County, are three storage reservoirs of the Fryingpan-Arkansas Project: Twin Lakes and Turquoise Reservoirs and Mount Elbert Forebay. The Pueblo Board of Waterworks also operates Clear Creek Reservoir on Clear Creek. From the Leadville area, the river flows in a southerly direction through Browns Canyon and turns east as it flows from Salida towards Canon City. The landscape is rugged as the river flows between narrow canyons and open parks. Below Canon City, the river enters the eastern plains landscape as it continues its course towards Pueblo Reservoir.

The assessment area comprises Twin Lakes, Turquoise and Clear Creek Reservoirs; the Arkansas River corridor downstream from those reservoirs to Pueblo Reservoir; and Pueblo Reservoir, for a total of about 148 river miles (see Maps 1 and 2).

B. Resource Managers and Responsibilities

Resource managers in this area who have taken an active role in this Water Needs Assessment include the U.S. Bureau of Reclamation, the U.S. Forest Service, U.S. Bureau of Land Management, and the Colorado Department of Natural Resources (DNR). Within DNR, the managing and cooperating agencies include Colorado Division of Wildlife, Colorado State Parks, and Colorado Division of Water Resources.

The U.S. Bureau of Reclamation is responsible for operation of the Fryingpan-Arkansas Project, including the operation of Turquoise Lake, Twin Lakes, and Pueblo Reservoir. The U.S. Forest Service manages public lands surrounding Turquoise Lake, Twin Lakes, and manages recreation on those reservoirs. The U.S. Bureau of Land Management manages public lands along the Arkansas River Corridor. The Bureau of Land Management and Colorado State Parks share in the management of the Arkansas Headwaters Recreation Area -- extending 148 miles between Leadville and Lake Pueblo State Park. Colorado Division of Wildlife is responsible for management of the state's fish and wildlife resources, and for management of 16 state wildlife areas within the Arkansas River watershed. The Colorado Division of Water Resources is responsible for administering the allocation of the state's waters according to individual water rights, and according to applicable state and federal laws.

C. Purpose of the Study

The purpose of this assessment is to:

- provide information about the water-dependent biologic, recreational, legal, and institutional water resource values that are of significance and importance. The assessment relates

river flows or reservoir levels in the upper Arkansas River basin to these water resource values

- provide information about the hydrologic regimes seen historically and at the present time in the river corridor and at reservoir operated by the U.S. Bureau of Reclamation
- provide information about the legal and institutional framework that guides the management of the Arkansas River and major reservoirs within the watershed

This assessment is the direct result of a memorandum of understanding (MOU) signed by the BLM, Bureau of Reclamation, The Forest Service and the Colorado Department of Natural Resources in 1992. These agencies have been cooperating and collaborating in the development of annual flow recommendations that help guide Reclamation's operations of the three Fryingpan-Arkansas Project reservoirs.

This assessment report will not be a decision document. However, it may be used to identify opportunities and to support future management decisions and strategies of appropriate agencies and institutions. Any future management actions supported by this report will require compliance with Federal (e.g. National Environmental Protection Act) and State laws.

The MOU stated that the primary objective of the assessment would be to "provide useful information about resource needs, water use constraints, and management opportunities for planners and decision makers". Specific objectives of the Assessment that were outlined in the MOU included:

(1) Develop an understanding of the hydrology and geomorphology of the river in conjunction with physical water management (i.e., streamflow, water storage, and release operations of the reservoirs).

(2) Develop an understanding of the relationships between stream flows, reservoir levels, and the resource values they affect. The resource values to be considered include: fish and wildlife habitat; recreational boating; fishing recreation; water quality; riparian habitat; and aesthetics.

(3) Analyze legal and institutional availability of water for management purposes.

(4) Identify and explain opportunities for meeting the needs of water dependent resources in the river and the reservoirs.

D. Existing Land and Water Management Framework

This assessment attempts to explain the legal and administrative framework governing the Arkansas River. Interstate compacts, federal laws, Colorado water law, numerous plans, and institutional arrangements govern the management of reservoir operations, water allocation, and natural resources in or adjacent to the Arkansas River. The Constitution of the State of Colorado recognizes the doctrine of prior appropriation as the principle means of allocating the usage of the waters of the State. As a result, the State engineer regulates numerous agricultural, municipal, industrial, and other water rights.

The Arkansas River includes both native water originating within the basin and water imported from the West Slope (Colorado River Basin) into the basin by the Bureau of Reclamation's Fryingpan-Arkansas Project and several other non-Federal diversion projects. Therefore, both the Colorado River Compact and the Arkansas River Compact affect management of the Arkansas River. The operation of the trans-basin diversion projects and several reservoirs located in the basin directly affects Arkansas River flows.

It is unlikely that any surface water remains available for appropriation in the Arkansas River Basin at this time. Water management in the upper Arkansas River Basin is complex and highly regulated under the authority of the State Engineer (CRS 37-92-301 and 501 et. seq.). There may be opportunities, however, for maintaining and

improving resource values within the existing legal, institutional, and management framework. Arrangements have been negotiated in the past to enhance certain water-dependent resource values (i.e., fisheries and float-boating activities on the Arkansas River). Negotiated agreements for reservoir releases, special-use permit stipulations, river exchanges, reservoir release substitutions, or point of diversion transfers are some of the options that may be available to preserve and enhance the various key resource values.

The following are existing agreements and management plans affecting the river and adjacent resources.

Fryingpan-Arkansas Project: The Bureau of Reclamation's Fryingpan-Arkansas Project was authorized by Congress "...for the purposes of supplying water for irrigation, municipal, domestic, and industrial uses, generating and transmitting hydroelectric power and energy, and controlling floods, and for other useful and beneficial purposes incidental thereto, including recreation and the conservation and development of fish and wildlife," (Act of August 16, 1962, P.L. 87-590, 76 Stat.389). Users of Project water are located in the Southeastern Colorado Water Conservancy District. Project reservoirs located in the Arkansas River Basin are Turquoise Lake and Twin Lakes near Leadville and Pueblo Reservoir near Pueblo. Recreation facilities and activities at the former two reservoirs are administered by the U.S. Forest Service and at the latter reservoir by the Colorado Division of Parks and Outdoor Recreation.

Arkansas Headwaters Recreation Area: Under a cooperative management agreement, the Bureau of Land Management and Colorado Division of Parks and Outdoor Recreation have implemented the Arkansas River Recreation Management Plan. This plan recognizes the interrelationship of recreation (e.g., boating, fishing) with the fisheries, aquatic habitats and aquatic ecosystems, riparian vegetation, and water quality of the Arkansas River. The agencies direct specific actions to maintain the quality of these resources and the opportunities they present. The Plan directs recreation management on the river corridor from Leadville to Pueblo Reservoir, and it directs coordination with the river corridor communities, local governments, land owners and water users.

Pike and San Isabel National Forest Plan: This U.S. Forest Service land-use plan provides general direction for water resources, including management adjacent to Twin Lakes and Turquoise Reservoirs. Specific management goals are to provide healthy, self-perpetuating plant communities, meet water quality standards, provide habitats for viable populations for wildlife and fish, and provide stable stream channels and still water-body shorelines. An earlier agreement with the U.S. Bureau for Reclamation states that efforts will be made to maintain specified minimum pool elevations for Turquoise Reservoir, however, project needs could dictate further lowering (1976 Memorandum of Understanding). This agreement also states that the Forest Service is responsible for administration and management of all recreation activities associated with the water surface of Turquoise Reservoir.

Lake Pueblo State Park Management Plan: This Plan governs the management of the 4,646 surface acre reservoir and its adjacent lands by the Colorado Division of Parks and Outdoor Recreation. The Reservoir is part of the Fryingpan-Arkansas Project, operated by the Bureau of Reclamation. Goals of the State Park Management Plan are to maintain: safe water-based recreation activities, a variety of complimentary land based recreation facilities, the quality of the reservoir fishery, and the viability of reservoir based concessionaires. Management is by agreement with the Bureau of Reclamation.

Division of Wildlife Management Guidelines for Upper Arkansas River Basin: Under these guidelines, the Division of Wildlife has set management objectives for the upper Arkansas River, upper Fryingpan-Arkansas Reservoirs, and Pueblo Reservoir. Management direction for the river corridor is to optimize the production of self-reproducing brown trout populations and encourage the development of self-reproducing rainbow trout fisheries. Within the basin the Division will maintain healthy populations of bighorn sheep,

deer, turkey, and waterfowl, while also protecting and enhancing blue herons, peregrine falcons, and bald eagles. For the upper reservoirs, the objective is to develop and sustain lake trout populations. The objective for Pueblo Reservoir is to optimize the production of warm water fish population.

E. Study Methodology

The assessment was a six-year effort involving a team of Federal and State agency professionals. Early phases of the study focused on literature and data collection, while latter phases of this effort dealt with analysis of data and reporting on the team's findings. The approach to the overall assessment involved five steps; (1) preliminary evaluation and design of specific studies; (2) hydrologic investigation for stream flows and reservoir levels; (3) evaluation of river flow- and reservoir level-dependent values and the water required to support those values; (4) analysis of the legal and institutional framework governing stream flows and reservoir levels; and (5) presentation of findings, including examples/scenarios that illustrate the tradeoffs associated with water management options. The following describes each of these steps:

(1) Preliminary Assessment

The preliminary assessment involved a thorough review of literature, discussions with pertinent field personnel, and a reconnaissance-level field assessment. Aerial photographs and maps were used to assist with designing specific studies. During this step, interagency cooperative agreements were arranged, and specific techniques or methods were selected. This step involved careful coordination between MOU agency's field personnel and other affected agencies, including offices of the U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and Colorado Department of Human Health and Environment. The result of the preliminary assessment provides documented summaries of literature reviews and selected methods.

(2) Hydrologic Investigation

The hydrologic investigation included analysis of historic streamflow and reservoir operations data to determine typical and extreme levels of river flow and reservoir storage contents. This data is relatively abundant in the basin and was analyzed to determine historical trends reflective of water management and use. Reservoir operation and river flow models were used to imulate various management opportunities. The hydrologic investigation provided the physical resource background for analyzing the water, both river and reservoir, dependency of the resource values identified in the next step. The results of the hydrologic investigation are documented in the section on analysis of existing water management.

All river flow measurements were taken at the Wellsville stream flow gage, located just east of Salida. Flows upstream and downstream from this point are different from this gage, due to input from tributaries and river gains and losses from irrigation return flows, seepage, and evaporation. Further information on hydrologic assumptions is available in the primary hydrology chapter of the Water Needs Assessment.

(3) Resource Values Assessment

Significant resource values were evaluated relative to dependence on reservoir levels, river flows or other water-related conditions. This step involved close interaction between project team members with different types of expertise. Results of the hydrologic investigation, including hydraulic and geomorphic analyses, were examined in conjunction with evaluations of resource values to develop resource specific river flow and reservoir level needs. This assessment documents the need for water to maintain, as well as enhance, fish and wildlife habitat, and recreational pursuits, such as rafting and fishing (i.e. flyfishing, spincasting, and float fishing).

For purpose of this assessment, the term "resource values" incorporates a multitude of objective natural resource related requirements (e.g., species such as brown trout need specific river conditions to survive) and subjective user preferences (e.g., activities such as rafting and fishing need flows to support user experiences). Data collection needed to supplement available literature and other information was performed during this step. Flow

preferences for river fish were calculated using brown trout as an indicator species. Rainbow trout needs are similar, and by using brown trout as an indicator species, the complexity of the report was reduced. Similarly, boating and fishing were selected from among many recreational activities that are dependent on reservoir levels and river flows.

The approach evaluated and identified reservoir levels and river flows to support the following resource values:

Fisheries - flow requirements for brown trout fishery and to develop the rainbow trout fishery in the Arkansas River
- upper reservoir levels and conditions to sustain and develop lake and rainbow trout populations
- Pueblo reservoir levels and conditions for black bass and crappie warm water fish production

Wildlife - flow and Pueblo Reservoir level requirements to maintain habitat for heron populations
- reservoir levels to maintain waterflow and shorebird populations
- flows and reservoir levels to protect bighorn sheep, peregrine falcons, bald eagles, osprey, golden eagles, and other sensitive, threatened, or endangered species; and maintain habitat associated with these animals

Boating - flows for various types of experiences and boats on the river
- flows for boating safety on the river
- reservoir levels for navigability and accessibility (e.g., shorelines, docks)
- Pueblo Reservoir levels for types of craft and experiences
- reservoir levels for adequate boater access

Fishing - flows and reservoir levels required for various types of fishing opportunities
- reservoir levels for access to shorelines

Water Quality - flows and reservoir operations that may indirectly affect resource values (e.g.; macroinvertebrates, primary productivity, water quality standards) by substantially changing water quality

Riparian/ Wetlands - flows required to maintain significant areas of riparian woody species
- upper reservoir levels that may be required to maintain vegetation in support of aesthetic values
- reservoir levels to maintain waterfowl populations
- flows and levels that may be required to protect candidate sensitive, threatened and endangered species

Aesthetics - upper reservoir levels required for desirable shoreline conditions

(4) Legal and Institutional Analysis
Existing and prospective water management was described and used to evaluate both the legal and institutional availability of water, which may be used to implement alternative management opportunities. Political considerations are also included in the analyses so that water management opportunities developed in the next step are both realistic and feasible. The result of this analysis documents water management options for both the river and reservoirs.

(5) Summary of Finding and Conclusions
In this step, the most significant findings and analysis from the previous chapters were described in a condensed fashion. The objective was to allow the reader to digest the major findings by reading one short chapter instead of the whole study. Graphs were created to illustrate the different flows needed to support various resource values, and to compare these flow needs with the flows presently provided by the Fryingpan-Arkansas Project.

II. Summary - Arkansas River Legal & Institutional Analysis

In response to the large numbers of demands placed upon it, the Arkansas River is one of the most intensively managed rivers in the western United States. By definition, a summary will omit many of the details regarding the laws, institutions, facilities, water rights, and water management operations that play a role in river management. Therefore, the focus of a summary must be upon elements of river management which have the greatest impact on the flows in the study reach between Turquoise Lake/Twin Lakes and Pueblo Reservoir.

Intensive river management efforts have not dramatically changed the annual hydrograph of the river in the study reach. Rather, river management has had the effect of maintaining peak spring runoff flows at the approximately the same level, has slightly increased late summer and early fall flows, and has increased October through March flows by an average of 100 cfs. The magnitude of the river management elements discussed below can be assessed by comparing the number of acre-feet involved to the average annual flow of the river for the 1990 to 1995 period at the Canon City stream gage, which was 550,000 acre feet.

A. Native River Flows and Senior Downstream Water Rights

By 1884, all the typical flows of the Arkansas River, exclusive of peak spring runoff and storm events, had been appropriated by agricultural users in the lower Arkansas River valley. Although some water use was occurring upstream of Canon City on the main stem and tributaries, the large number of downstream water rights insured that most native flows stayed in the river in the river at least to Pueblo. The ability of these water rights to pull water down to the lower Arkansas Valley was enhanced when ditch companies constructed and obtained decrees for more than 400,000 acre feet of reservoir space to store diversions. Today, there are 23 major ditch systems diverting water between Pueblo and the Colorado-Kansas border.

B. Early Transmountain Diversions and Upper Basin Storage Facilities

By 1935, 43,000 acre feet was imported annually from other basins into the Arkansas River basin. Some of this total was made up of several large, open ditches that crossed the continental divide, but the majority of this amount was comprised of imports through the Busk-Ivanhoe System and the Twin Lakes Project. Development of the Busk-Ivanhoe System allowed diversion of water from the headwaters of the Fryingpan River to Lake Fork Creek via the Carlton Tunnel. Development of the Twin Lakes Project allowed importation of water from the headwaters of the Roaring Fork River to the North Fork of Lake Creek via the Twin Lakes Tunnel.

At the time of construction, these systems provided water exclusively for agricultural use in the lower Arkansas River Valley. In cases where these diversions were not stored high in the basin, the systems had the effect of increasing flows during spring runoff and early summer in the main stem. These systems continue to operate today, although some of the imported flows are directed to storage before being released to the main stem. Today, the Twin Lakes system imports an average of 54,500 acre-feet annually, and the Busk-Ivanhoe System imports an average of 5,081 acre feet annually. The Wertz, Ewing, and Columbine ditches import an average of 4,971 acre feet annually.

Significant storage facilities were also built in the upper basin to store both native water and imported water. In 1900, the Colorado Canal Company constructed Twin Lakes Reservoir on Lake Creek (an enlargement of a natural reservoir), with a capacity of 54,452 acre-feet. CF&I Steel Company completed construction of Sugarloaf Reservoir in 1902, with a capacity of 17,416 acre feet. This reservoir allowed storage of native water from the Lake Fork Creek and storage of water from other Arkansas River tributaries by exchange. Finally, Otero Canal Company constructed Clear Creek Reservoir from 1902 to 1907, with a capacity of 11,386 acre-feet. Construction of these reservoirs had the effect of slightly reducing spring peak flows by capturing runoff, and had the effect of increasing late summer flows by releasing stored water for irrigation purposes.

C. Municipal Water Supply Systems

Starting in the 1950's, several of the agricultural water supply systems were purchased in whole or in part by municipalities who sought an assured water supply for growing populations. In 1955, Pueblo Board of Waterworks purchased Clear Creek Reservoir from the Otero Canal Company. In the early 1970's, the Twin Lakes transmountain diversion system and reservoir were purchased by Colorado Springs, Aurora, Pueblo, and Pueblo West. The change of ownership means that instead of an exclusive pattern of spring storage and summer release for agriculture use, these reservoirs are now managed to provide year-round supplies for the municipalities. Since they are part of complex municipal supply system, releases of stored water to the main stem may occur at any time of the year. In addition, if part of the yield of these reservoirs is not needed for municipal use, water may be sold to other customers, which results in releases timed to meet the customer's need.

The City of Colorado Springs has an extensive water supply which taps multiple watersheds, but only a portion of this system has the capability to affect main stem flows between the headwaters and Pueblo. The South Pikes Peak System and the Penrose-Rosemont System divert water out tributaries which enter the Arkansas River between Canon City and Pueblo. Water from the Homestake Project, which diverts water from the Eagle River system, and the Blue River Project, which diverts water from Summit County, are transported directly to Colorado Springs and do not enter the main stem of the Arkansas River. Colorado Springs also obtains water from the Fryingpan-Arkansas Project (discussed in next section). This water is delivered to Colorado springs via the Otero Pipeline, which takes water directly from Twin Lakes, and transports it over Trout Creek Pass to the City's distribution system. Finally, Colorado Springs obtains water supplies via the Fountain Valley Conduit, a pipeline system which starts at Pueblo Reservoir, and runs northward toward Colorado Springs. If the city chooses this delivery route for water, rather than the Otero pipeline from Twin Lakes, then the main stem may see additional flows as the water is delivered to Pueblo Reservoir for placement in the conduit.

The City of Colorado Springs and Aurora have also purchased water rights from lower Arkansas Valley farms, and have received permission from the water court to transfer those water rights to municipal use. This permission means that the water can be diverted at the Otero Pipeline, high in the basin near Twin Lakes, rather than flowing down the river to be diverted in the lower valley. As of 1997, less than 15,000 acre feet have been transferred in any one water year, but the total amount available for transfer is approximately 23,400 acre-feet.

D. Fryingpan-Arkansas Project

Between 1962 and 1980, Reclamation constructed or enlarged four storage dams and reservoirs in the basin, creating a total storage capacity of almost 630,000 acre feet:
(1) Turquoise Lake five miles west of Leadville with a capacity of 120,478 acre-feet
(2) Mount Elbert Forebay Dam and Reservoir at the base of Mt. Elbert, with a capacity of 11,143

acre feet (3) Twin Lakes Dam and Twin Lakes at the east end of Independence Pass, with a capacity of 140,855 feet (an enlargement of a natural lake) (4) Pueblo Dam and Reservoir, just west of the City of Pueblo, with a capacity of 357,000 acre feet. In addition, between 1965 and 1981, Reclamation constructed and enlarged the west slope collection system which conveys water to these reservoirs through the Charles H. Boustead Tunnel. The annual amount of water imported to the basin each year has averaged 69,200 acre-feet.

The operating objectives of the Fryingpan-Arkansas Project are:

- maximize the storage of Project water from both west slope and east slope
- fill Turquoise and Twin Lakes each year during the summer
- keep Turquoise and Twin Lakes full during the summer and early fall to provide recreational opportunities (this objective has been added since the Project was originally authorized by legislation)
- minimize the loss of Project water to evaporation
- maximize generation at the Mt. Elbert Power Plant
- fulfill contractual obligations for providing storage space and conveyance facilities
- deliver water at the time and place of needs to customer of the Southeastern Colorado Water Conservation District

In general, this means that the upper reservoirs, Turquoise Lake and Twin Lakes, are lowered prior to runoff in May to accommodate the predicted water availability from the east slope and west slope diversions. Since 1990, Reclamation has attempted to accomplish the lowering of upper reservoirs by April, to fulfill flow recommendations from the Colorado Department of Natural Resources. Twin Lakes and Turquoise Reservoir are typically filled by mid-July. From mid-July through September, releases from these reservoirs are roughly equivalent to inflow of native (non-imported) water. Since 1990, Reclamation's practice has been to gradually deliver water from the upper reservoirs to Pueblo Reservoir between October and March. This water will then be delivered to Southeastern customers upon demand. Whenever possible, Reclamation manages its releases from upper basin reservoirs in accordance with recommendations from the Colorado Department of Natural Resources that are designed to enhance the flow regime of the river to benefit riverine habitat and recreation. This practice has been implemented since 1990 with the support of the Southeastern Colorado Water Conservancy District.

The construction of the Fryingpan-Arkansas Project allowed Reclamation to sign storage contracts with parties who had a need to store the yield of previously established water rights. These contracts include:

Typically Stored in Turquoise Reservoir
17,416 Acre Feet - City of Colorado Springs
5,000 Acre Feet - City of Aurora (original shares of Busk-Ivanhoe, Inc.)
5,000 Acre Feet - Pueblo Board of Water Works (original shares of Busk-Ivanhoe, Inc.)
30,000 Acre Feet - City of Colorado Springs and City of Aurora

Typically Stored In Twin Lakes
54,452 Acre Feet - Twin Lakes Reservoir and Canal Company

Frequently, these storage contracts, as well as others signed on a short-term basis, are employed by water users to execute exchanges. These exchanges allow water from lower Arkansas Valley locations and other upper basin locations to be moved to Turquoise Reservoir and Twin Lakes. Moving water to this location allows easy delivery to municipal supply systems via the Otero Pipeline. Reclamation also stores water for lower basin users at Pueblo Reservoir under a decreed "Winter Water Storage Program." This program allows some water rights holders, primarily agricultural users who historically used water during the winter, to store the yield of those water rights

in Pueblo Reservoir from November 15 to March 14 for irrigation at a later time.

E. Arkansas River Compact of 1948

While the administration of the compact has major impacts on water use in the lower Arkansas Valley, its impact on stream flows between Twin Lakes and Pueblo Reservoir is much more limited. The compact ratified irrigation as a legitimate use for John Martin Reservoir, which was previously approved only for flood control. Therefore, John Martin became a major storage facility with a 1948 priority, which is senior to water rights for the Fryingpan-Arkansas Project. Project facilities cannot store native flows until John Martin Reservoir is full. When this occurs, the main stem of the Arkansas may see a decrease in streamflow as upper basin storage captures a portion of the native flows.

F. Annual Flow Management Program

In 1990, Reclamation and the Colorado Department of Natural Resources signed an agreement under which Reclamation would attempt to provide flows to better support natural resource values. There is no legal obligation upon Reclamation to provide the flows, and the program must be operated within the context of legally required storage and deliveries for water users. DNR makes its flow recommendations via an annual letter to Reclamation each Spring. The annual letter has typically included the following six components:

- minimum year round flow of at least 250 cfs to protect the fishery
- flows from mid-November through April not less than 5" below the height of the river between Oct. 15 - Nov. 15 to protect and incubate brown trout eggs
- flows April 1 - May 20 between 250-400 cfs for egg hatching and fry emergence
- augment flows during the July 1 to August 15 period to create flows of at least 700 cfs for recreational purposes
- limit daily flow changes to 10-15% of flows
- if possible, reduce flows after Labor Day to levels recommended by Colorado Division of Wildlife

G. Legal and Institutional Opportunities For Water Management

There are numerous opportunities for improving water management to better meet the needs of water users and the natural environment. However, all of these opportunities involve numerous issues and concerns, affected parties, and legal constraints. These opportunities include:

- Modified Management of Existing Storage and Conveyance Facilities
- Expanded or New Storage Capacity
- Southern Delivery System For City of Colorado Springs
- Temporary Water Transfers
- Arrangement with Municipal Water Providers
- Expanded Season of Exchanges
- Increased Water Imports

Most of the water users in the basin have agreed that to better meet water needs, improved storage management should be thoroughly investigated and tried before other options are explored and implemented. To this end, Southeastern Colorado Water Conservancy District is coordinating a study of storage needs and storage management within the basin.

III. Summary - Hydrologic Analysis of Changes in Arkansas River Flows Since 1889

The hydrologic analysis of flows was divided into three time periods, to reflect major changes in river management. The first designated time period, 1889-1910, reflects the earliest date for which continuous flow records are available, and represents a fairly natural, unregulated system before 1900. Between 1900 and 1910, the system began to experience the effects of limited water imports and the construction of Clear Creek, Twin Lakes, and Sugarloaf Reservoirs in the upper basin. The second designated time period, 1910-1960, reflects a time period when water management was fairly stable, without any major new water management facilities. Transbasin diversions, overall storage capacity, and active storage management increased incrementally, but did not dictate extensive alterations in how the river was managed. The third period, 1982-1995, reflects a period when the Fryingpan-Arkansas Project was coming on line, along with associated institutional changes in how water was managed and allocated. The 1960 to 1982 period was not analyzed because the timing and magnitude of flows fluctuated as new water storage and import systems came on line.

The overall net effects of the period from 1890-1910 are a slight reduction in November through April flows, a reduction in spring runoff flows (May-June), and an increase in August - September flows. These effects are predominantly the result of upper basin storage put into service after 1900. Mean flows for November through April flows prior to 1901 are approximately 420 cfs, and mean flows for November through April post-1901are approximately 350 cfs. Mean daily flow before 1901 for the August 1-15 period was 650 cfs, while after 1901, the mean daily flow for the August 1-15 period was 770 cfs.

Flows during the 1910-1960 period were approximately the same as the 1889-1910 period during fall, winter, and spring. However, due to the release imported of water that was stored on the east slope during runoff, July and August flows increased significantly. The mean daily flow for August 1 - August 15 for the 1910-1960 period was approximately 1000 cfs, compared to 770 cfs from 1901 to 1910. This is an increase of 230 cfs from the 1901-1910 period, and is almost completely attributable to transbasin imported water.

Flow analysis during the 1982-1995 period is complicated by several factors. Completion of the Fryingpan-Arkansas project created tremendous flexibility in the process of water storage and movement. In addition, the wettest period is on record is from 1982-1987, 1989-1992 is extremely dry, and 1995 is the wettest year on record. Finally, an annual flow management program was started in 1990. This program sets target flow ranges for 12 months of the year, and it involved augmentation of late July and early August flows is some water years.

Flow augmentation appears to continue flow levels that have been present since a significant change that occurred in the early 1900's. Even though the flow augmentation program was operated during the 1990-95 period, there were many days in the August 1-15 period which experienced flows of less than 700 cfs because other factors were at work on the river which reduced flows. The percent of days which flows exceeded 700 cfs during the August 1 to August 15 period is as follows:

Prior to 1910	1910-1960	1982-1989	1990-1995
40%	75%	80%	77%

In contrast to late summer, the effects of institutional management since 1982 are clearly evident during the November-April period. Since 1982, an average of 40,000 acre feet of additional water is passed during this period. Mean daily flows have increased approximately 100 cfs during the winter months, in comparison to the 1910-1960 period. This movement can be accounted for by the new movement of water from the upper reservoirs to lower basin storage to allow for spring runoff storage in the upper basin.

IV. Operation of the Frying Pan - Arkansas Project

A. Explanation of water management objectives and actions to optimize yield

The purpose of presenting a baseline hydrograph for the Arkansas River is to compare the water needed to support natural resource values with flows designed to optimize water available for consumptive uses. The baseline Arkansas River hydrograph presented in this section represents Arkansas River flows from 1982 to 1995, incorporating Fryingpan-Arkansas operations during that time period. When utilizing the baseline hydrographs in this section, the following limitations need to be kept in mind:

The Fryingpan-Arkansas Project regulates only a fraction of total flows in the upper Arkansas River basin, and other legal/institutional factors play a large role in determining flow rates. However, the Fryingpan-Arkansas Project is among the largest of many factors in determining flow rates experienced in the Arkansas River corridor.

This baseline does not mimic all of the historic operations of the Project, because significant changes in flows have been implemented as various components of the project have come on line, and as Reclamation gained more experience in operating a new project.

The 1982-1995 period may not be representative of the entire range of hydrologic conditions that could be experience in the future.

This baseline represents an operation which is in variance from the DNR flow recommendations that have been implemented since 1990.

This baseline developed in this section is a representation of what flows would be expected to occur in the river corridor if the Fryingpan-Arkansas Project (Project) were to be operated, today, to best achieve the following goals:

- Maximize storage of Project water
- Minimize unnecessary spilling of non-Project water
- Minimize loss of Project water to evaporation
- Maximize energy generation at the Mt. Elbert Powerplant

Full implementation of these goals would entail the following Project operations:

- Water would be evacuated from Turquoise Lake and Twin Lakes and stored in Pueblo Reservoir, via releases through the Mt. Elbert Conduit and from Twin Lakes Dam, before the spring snowmelt. Releases would be in a quantity sufficient to allow refilling of the two reservoirs with water imported from the West Slope by mid-July.

- Water would not be evacuated from the upper reservoirs before March because an accurate forecast of spring runoff can not be made until a significant portion of the high elevation snowpack has accumulated.

- It is important that water be evacuated from Turquoise Lake before the runoff due to the limited capacity of the Mt. Elbert Conduit. The capacity of the Mt. Elbert Conduit, which carries water from Turquoise Lake to Twin Lakes, is significantly less than the combined spring inflow of the transmountain tunnels and native Lake Fork flows during the runoff. If sufficient space in Turquoise Lake has not been evacuated, then releases from Sugarloaf Dam to Lake Fork would be necessary. Releases in excess of the minimum

required releases would be necessary to avoid foregoing West Slope imports after the Lake fills. Any water released to Lake Fork in excess of the minimum requirement is a loss of energy generation at the Mt. Elbert Powerplant.

In a year of normal spring runoff, releases from the upper reservoirs would be made in March and April such that the entire Project storage capacity of Turquoise Lake is evacuated. Releases in May and June, the height of the spring runoff, would be avoided because the entire safe channel capacity of Lake Creek below Twin Lakes Dam is quite often needed during that time period for the required bypass of the native inflow to Twin Lakes. The native inflow to Twin Lakes includes native flows of Lake Fork and Halfmoon Creek diverted through the Mt. Elbert Conduit, in addition to the native flow of Lake Creek. If the safe channel capacity below Twin Lakes Dam is reached, then diversions of native water from Lake Fork and Halfmoon Creek would be reduced or discontinued and energy generation would be foregone.

In a year of heavy spring runoff, these releases would start in March and continue through May in order to evacuate the Project storage capacity of Twin Lakes in addition to that of Turquoise Lake. After all Project storage space is filled in the upper reservoirs, releases from Twin Lakes Dam and, if necessary, Sugarloaf Dam would be made to avoid foregoing imports of Project water from the West Slope. An unavoidable bypass of the Mt. Elbert Powerplant would occur in such years.

In a year of below average spring runoff, releases from the upper basin reservoirs would be discontinued before the end of April to avoid storing more water in Pueblo Reservoir than is necessary. Any unnecessary storage of water in Pueblo Reservoir represents a risk of foregoing Winter Water storage in the Reservoir in the following winter and spring. Unnecessary storage of Project water in Pueblo Reservoir also causes greater losses of Project water to evaporation. The evaporation from Pueblo Reservoir is greater than from the upper reservoirs.

The evacuation of water from the upper reservoirs could be limited, in any kind of runoff year, by the lack of Project storage space in Pueblo Reservoir. The available space in Pueblo Reservoir does not correlate to the runoff in any single year because Pueblo Reservoir is designed to hold multiple years of water supply. Consecutive dry years draw the reservoir down and consecutive wet years fill it up.

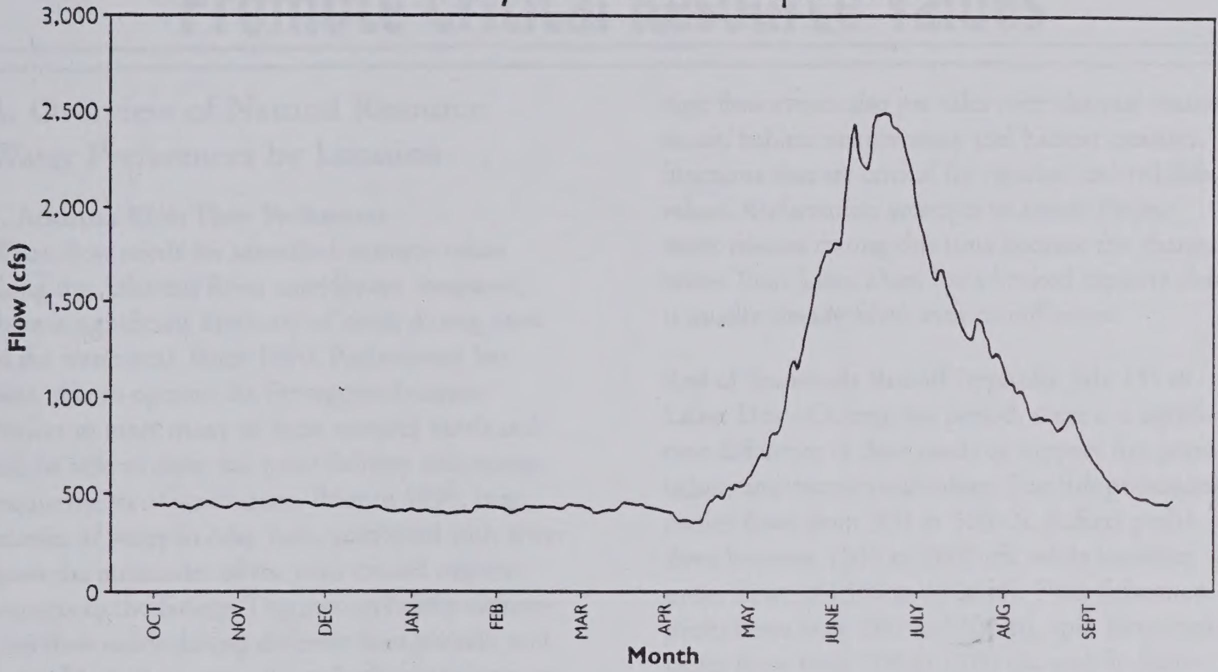
After the upper reservoirs fill in July, no release of Project water would be made until the following March. The only exceptions would be direct releases of imported water in a heavy runoff year, and releases for Project water demands downstream of Pueblo Reservoir in the event that all Project water is depleted from Pueblo Reservoir. Delaying any further releases until March allows the upper reservoirs to remain as full as possible. This reduces evaporation losses and, as a side benefit, enhances flatwater recreation at the reservoirs.

B. Baseline Arkansas River Hydrograph Incorporating Fryingpan-Arkansas Project Operations

The following baseline Arkansas River hydrograph was developed by using flows and Project operations that were observed from 1982 through 1995. Project operations that were designed to fulfill flow management recommendations from the Colorado Department of Natural Resources have been deleted from the hydrograph whenever a separate accounting of those operations was recorded. The purpose of these adjustments was to create a baseline Arkansas River hydrograph that reflects expected flows when the project is operated to optimize water available for consumptive use and for hydroelectric generation. In the next chapter, this baseline hydrograph will be compared to the flows needed to support natural resource values.

Arkansas River Flows at Wellsville 1982 to 1994 *

Mean Daily Flow: October 1 - September 31



* Water released form upper basin reservoirs as part of the flow augmentation program between July 1 and August 15 have been subtracted from this hydrograph. Water released during other parts of the year as part of the annual flow management program have not been subtracted from this hydrograph because those releases are not accounted for separately from other water deliveries.

V. Water Needed to Protect or Promote Critical Resource Values

A. Overview of Natural Resource Water Preferences by Location

1. Arkansas River Flow Preferences

When flow needs for identified resource values along the Arkansas River corridor are compared, there is significant similarity of needs during most of the water year. Since 1990, Reclamation has been able to operate the Fryingpan-Arkansas Project to meet many of these resource needs and still be able to meet the water delivery and storage requirements of water users. Prior to 1990, large releases of water in May June, combined with lower flows the remainder of the year, created negative impacts to the fishery. This section briefly summarizes flow needs during different time periods, and it provides information about Reclamation's typical flow management practices during those periods.

November l to Start of Spring Runoff (typically around April 15) - The river's fish population and angling opportunities are well-supported by flows ranging from 300 cfs to 500 cfs. The riparian community is dormant during this time, and very little boating occurs. Since 1990, Reclamation has typically transferred water from the upper reservoirs to Pueblo Reservoir during this time period. These releases have seldom created a situation in which reservoir releases caused total flows to exceed 500 cfs, and they have also made it possible to meet flow targets for supporting fishery values after April 15.

Snowmelt Runoff Period (typically April 15 to July 15) - Higher flows experience during this period are not optimal for the fish population or for angling, but spring runoff is an uncontrolled, natural function of rivers. Resource managers recognize that there must be a window to pass significant quantities of water. Conversely, the annual runoff periods usually provides flows that satisfy needs for recreational boating. The variability of the annual high flow events also provides river channel maintenance, habitat maintenance and habitat creation functions that are critical for riparian and wildlife values. Reclamation attempts to avoids Project water releases during this time because the channel below Twin Lakes Dam has a limited capacity that is usually already filled with runoff water.

End of Snowmelt Runoff (typically July 15) to Labor Day - During this period, there is a significant difference in flow needs to support fish populations and recreational values. The fish population prefers flows from 300 to 500 cfs. Rafters prefer flows between 1500 to 2000 cfs, while kayakers prefer flows of 1300 to 1500 cfs. Float fishermen prefer flows from 900 to 1200 cfs, spin fishermen prefer flows from 700 to 1200 cfs, and fly fishermen prefer flows from 400 to 500 cfs. If the annual flow management program were not in place, Reclamation would not release water during this period to avoid unnecessarily storing water in Pueblo Reservoir. Water unnecessarily stored in Pueblo Reservoir increases the risk of spilling Winter Water, slightly increases the evaporation loss to Project water, and may adversely impact flatwater recreation at the upper reservoirs.

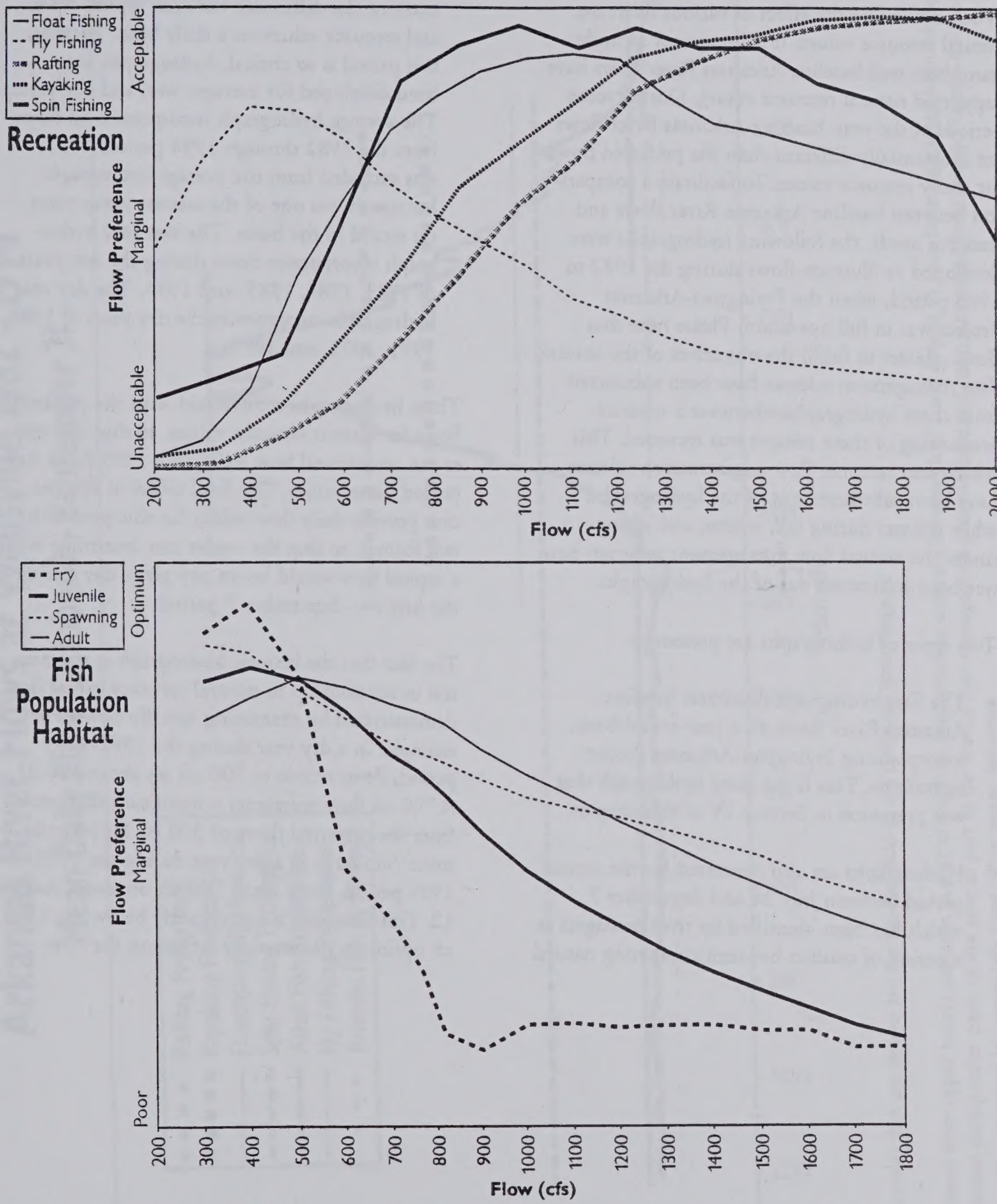
Labor Day - October 31 - Resource needs are similar during this period. Fish population and angling needs are well-supported by flows from 300 to 500 cfs, as is the riparian zone at the end of its growing season. While boating use would be better supported by flows of at least 1,000 cfs, the demand for such use declines sharply after Labor Day weekend. If the annual flow management program were not in place, Reclamation would not make water releases during this period for the same reasons cited in the discussion for the July 15 to Labor Day period.

Please see the charts on following the following pages for a graphical illustration of flows needed to support natural resource values.

Arkansas River
Summary of Water Needs for Resource Values

Month	Reference Points: 1982-1995 Wellsville average daily flows (cfs)	Fisheries Needs	Boating Needs		Angling Needs			Wildlife & Riparian Needs	Other Needs
			Rafting	Kayaking	Fly	Spin	Float		
November	439	Flow Preference 300-500			Flow Pref 400 - 500	Flow Pref 700 - 1200		Natural Hydrograph (variability inflows is positive)	
December	452								
January	446								Dilution of early snow melt benefits water quality during March & April
February	454							Except at high flows, changes in cfs do not have large impact	
March	481						Flow Pref 900 - 1200		
April	490		Flow Preference 1500 - 2000	Flow Preference 1300 - 1500					
May	1,189	Spring runoff flow for channel maintenance							
June	2,568							Lowest flows impact ground-water levels	
July	1,727	Flow Preference 300 - 500							
August	956								
September	477								
October	402								

Arkansas River Assessment Flow Preferences



Note: Fish population habitat preferences are shown for the Wellsville Stockyard location, which is considered representative of the reach from Turquoise Lake to Pueblo. Flows below 300 cfs were not modeled.

a. Comparison of Natural Resource Flow Preferences to Baseline Arkansas River Flows

When evaluating the effect of various flows on natural resource values, it is important to understand how well baseline Arkansas River flows have supported natural resource values. During some periods of the year, baseline Arkansas River flows are substantially different than the preferred flows for many resource values. To facilitate a comparison between baseline Arkansas River flows and resource needs, the following hydrographs were developed to illustrate flows during the 1982 to 1995 period, when the Fryingpan-Arkansas Project was in full operation. Please note that flows releases to fulfill the objectives of the annual flow management releases have been subtracted from these hydrographs whenever a separate accounting of these releases was recorded. This means that summer flow augmentation releases have been subtracted out of the hydrographs, while releases during fall, winter, and spring under the annual flow management program have not been subtracted out of the hydrographs.

Two types of hydrographs are presented:

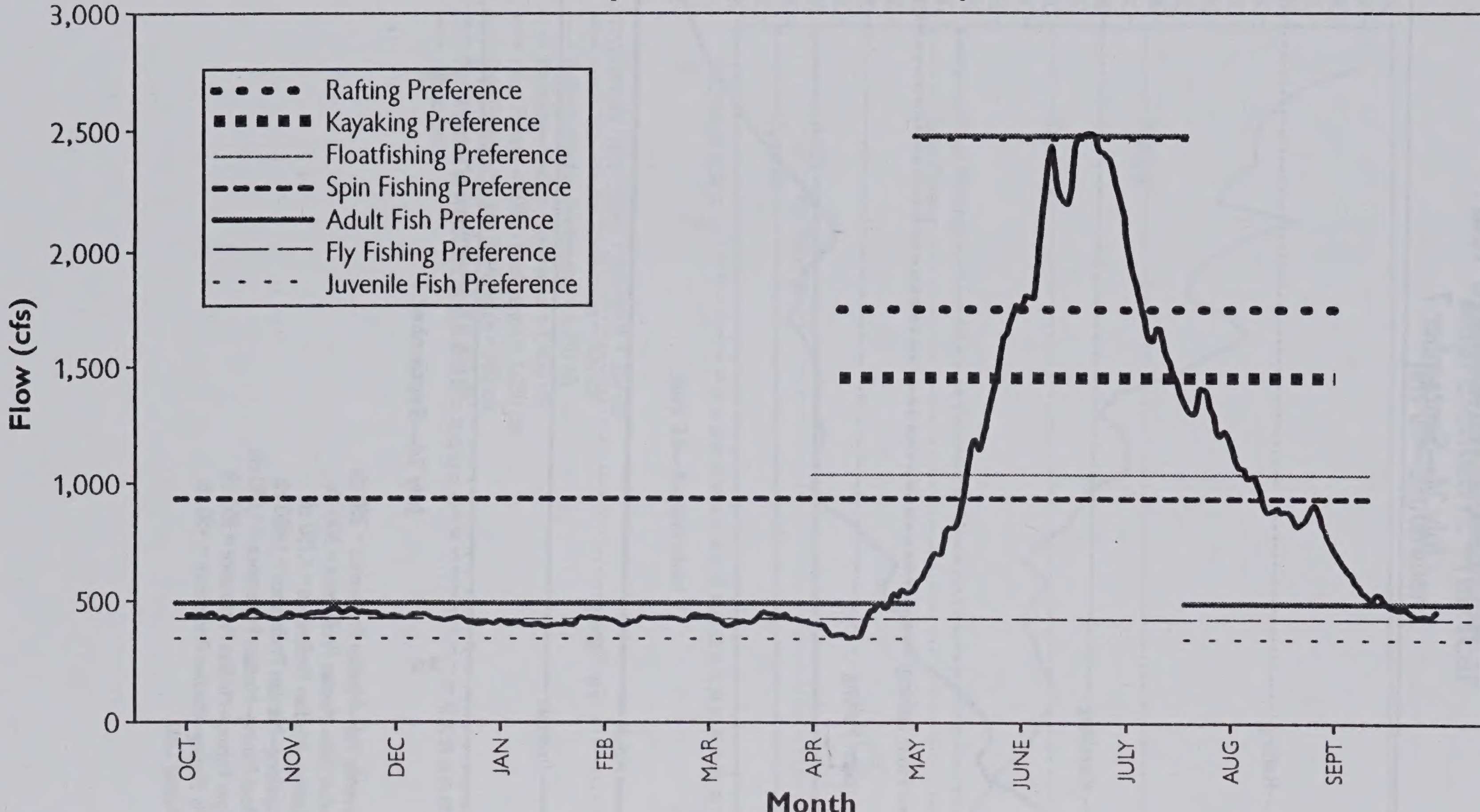
- The first hydrograph illustrates baseline Arkansas River flows on a year-round basis, incorporating Fryingpan-Arkansas Project operations. This is the same hydrograph that was presented in Section IV of this chapter.
- Hydrographs are also presented for the annual period between July 24 and September 7, which has been identified by river managers as a period of conflict between competing natural resource values. The additional detail provided in these hydrographs allows the reader to examine the difference between typical flows and resource values on a daily basis. Because this period is so critical, hydrographs have been developed for average, wet, and dry years. The average hydrograph incorporates all flows from the 1982 through 1994 period. 1995 was excluded from the average hydrograph because it was one of the wettest water years on record in the basin. The wet year hydrograph incorporates flows during the wet years of 1983, 1984, 1985, and 1995. The dry year hydrograph incorporates the dry years of 1988, 1991, 1992, and 1994.

These hydrographs are overlaid with the preferred flows for various resource values, so that the reader can understand how well 1982-1995 flows supported those values. The final tables in this section provide daily flow values for this period in text format, so that the reader can determine what a typical flow would be on any given day during the July 24 - September 7 period.

The fact that the historic hydrograph is not neutral in relationship to natural resource values is demonstrated by examining specific flows. For example, in a dry year during the 1982-1995 period, flows recede to 700 cfs on about July 21. A 700 cfs flow represents a significant departure from the preferred flows of 350 cfs for juvenile trout. Similarly, in a dry year during the 1982 to 1995 period, flows reach 500 cfs on about August 12. This flow that is significantly below the 1500 cfs optimum preferred by rafters on the river.

Arkansas River Flows at Wellsville 1982 - 1994

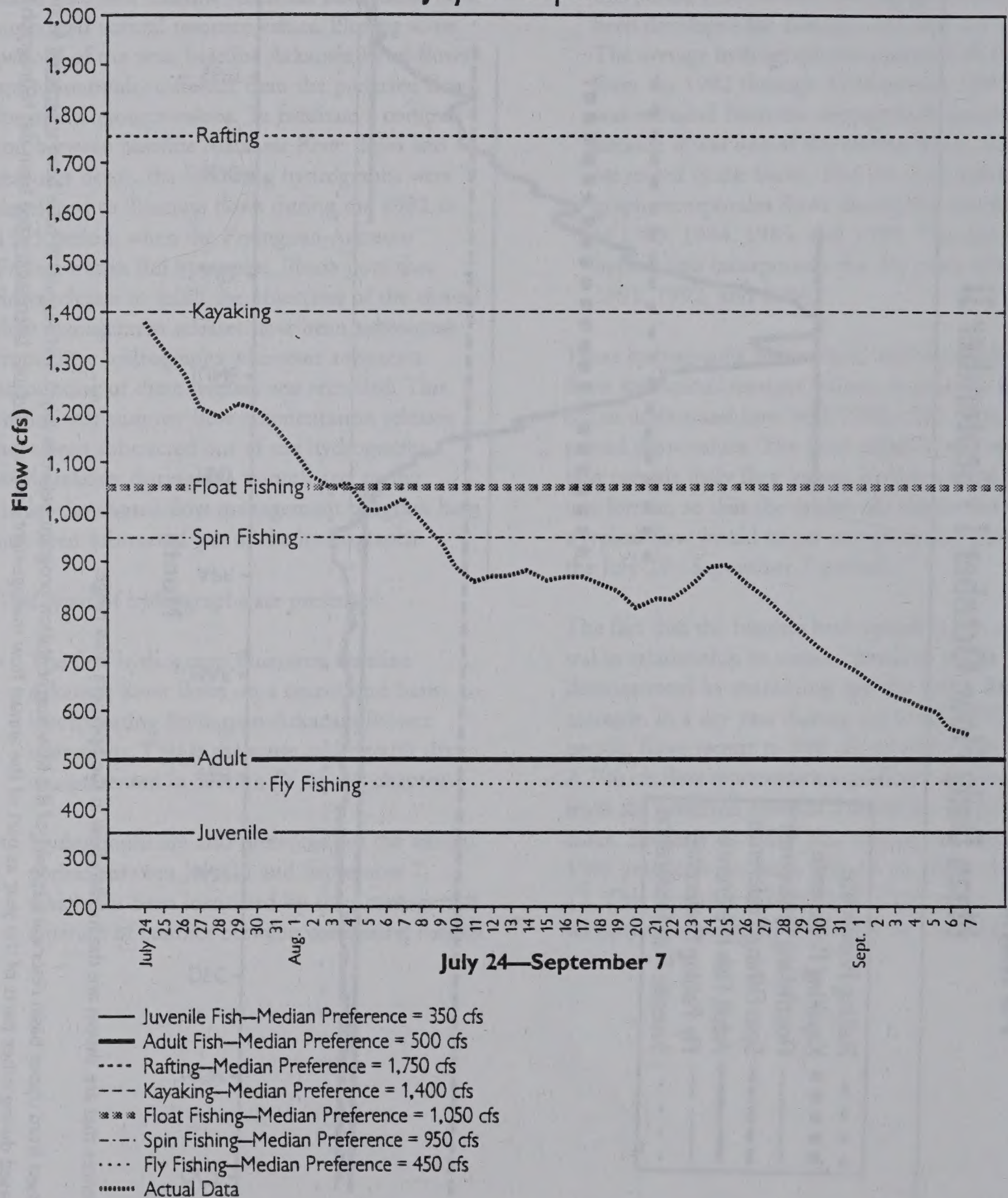
Mean Daily Flow: October 1 - September 31



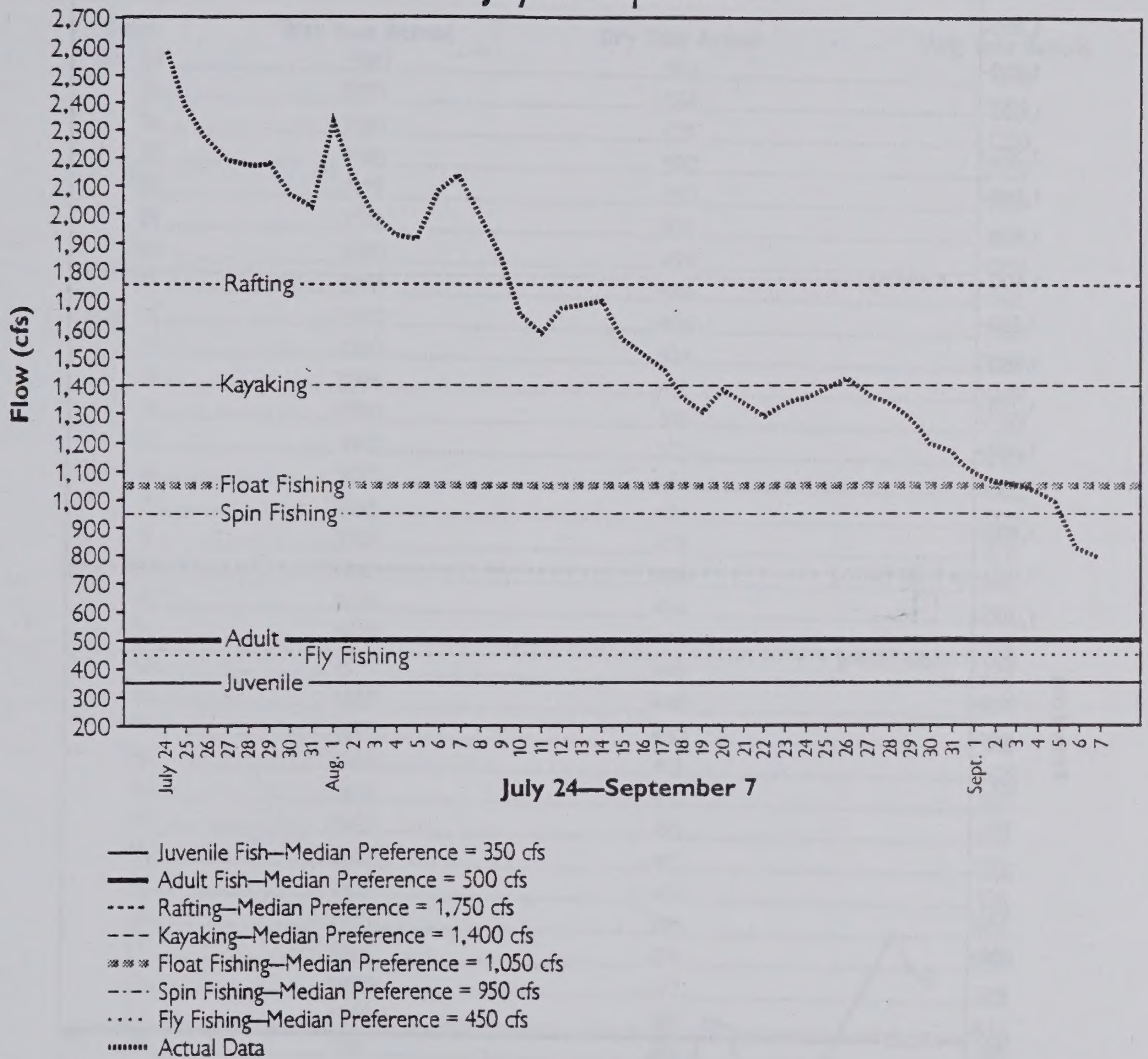
Note: Flow preferences that are shown are the median flow in the optimum flow range.

Note: Water released from upper basin reservoirs as part of the flow augmentation program between July 1 and August 15 have been <u>subtracted</u> from this hydrograph. Water released during other parts of the year as part of the annual flow management program <u>have not been subtracted</u> from this hydrograph because those releases are not accounted for separately from other water deliveries.

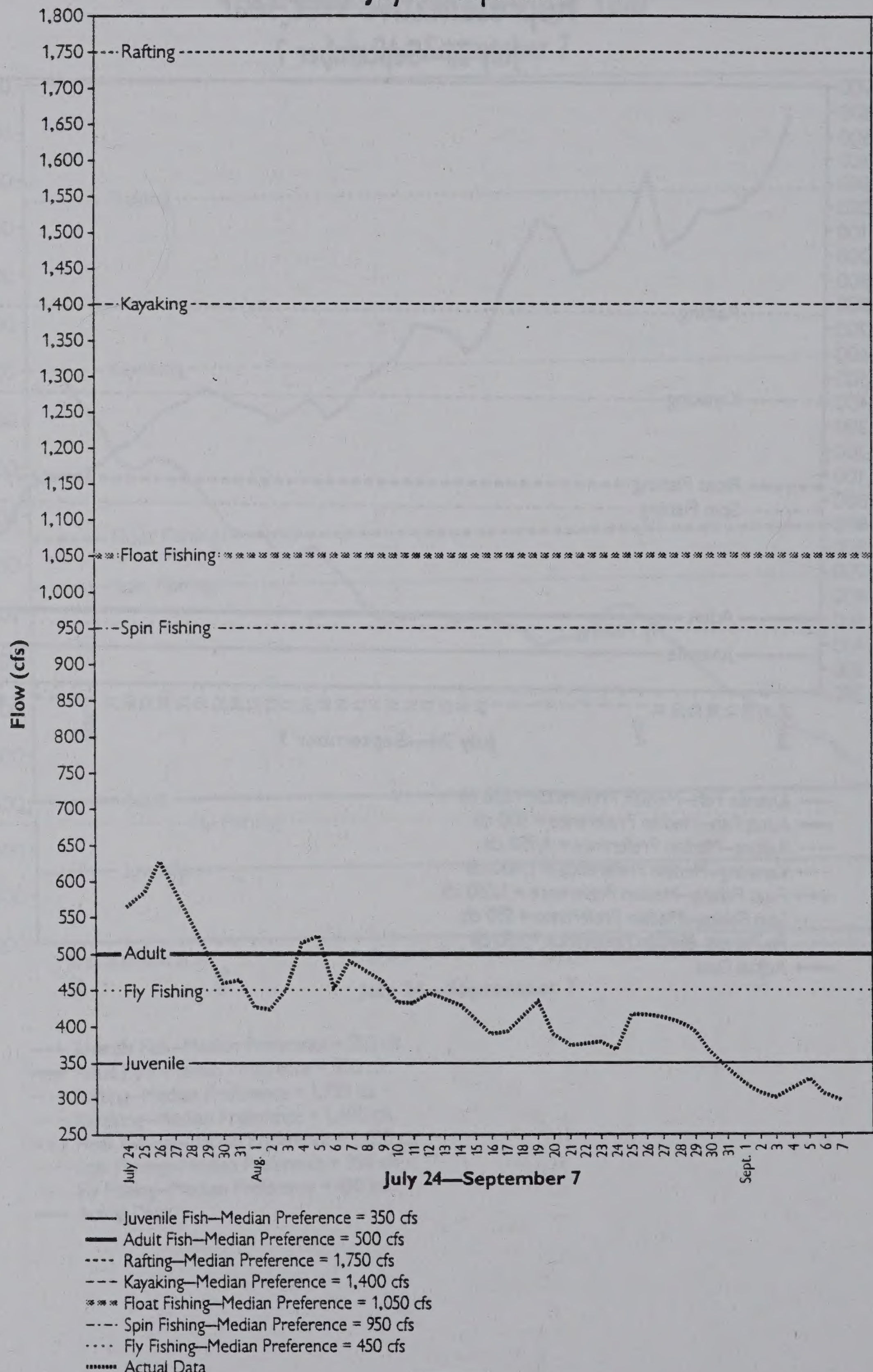
Arkansas River at Wellsville
Representative Average Year
July 24—September 7



Arkansas River at Wellsville
Representative Wet Year
July 24—September 7



Arkansas River at Wellsville
Representative Dry Year
July 24—September 7



Arkansas River at Wellsville

Actual Measured Data (cfs)

Representative Wet, Dry, and Average Years

Date	Wet Year Actual	Dry Year Actual	Avg Year Actual
Jul 24	2580	566	1380
25	2373	586	1323
26	2263	629	1286
27	2188	590	2309
28	2173	550	1189
29	2178	505	1216
30	2070	459	1203
31	2018	466	1166
Aug 1	2330	426	1120
2	2130	424	1069
3	2005	451	1049
4	1930	516	1050
5	1915	525	1003
6	2075	454	1002
7	2145	491	1025
8	2000	478	979
89	1860	464	942
10	1655	434	886
11	1585	434	859
12	1675	447	868
13	1685	440	871
14	1695	430	880
15	1560	412	8609
16	1505	390	865
17	1455	395	866
18	1360	415	852
19	1305	436	835
20	1395	390	805
21	1335	375	820
22	1300	377	825
23	1340	380	848
24	1361	368	886
25	1395	418	889
26	1431	415	853
27	1370	413	822
28	1344	407	789
29	1283	394	753
30	1200	364	722
31	1164	343	693
Sep 1	1096	323	675
2	1059	309	645
3	1053	303	627
4	1032	315	611
5	989	329	596
6	829	309	561
7	801	299	552

2. Turquoise Reservoir, Twin Lakes, and Clear Creek Reservoir Water Level Preferences

The various resource values have similar water level needs at Turquoise Reservoir and Twin Lakes. All resources are benefitted by maintaining full reservoirs as much of the time as possible, and with as little water level fluctuation as possible. However, resource managers recognize that reservoir operations must continue in order to make water deliveries to water users. With this in mind, resource values are best supported when the reservoirs are kept as full as possible during May, when the vegetation growing season begins and when water temperatures become warm enough to support significant biological activity among fish populations.

Once the reservoirs are full at the end of spring runoff (typically around July 15) resource values are best supported if reservoirs are not drawn down by more than 10 feet between the fill date and October 1. Drawdowns of more than 10 feet reduce the primary productivity (basic food production) of the reservoirs, and reduce the area of feeding habitat for fish. In addition, drawdowns of more than 10 feet affect the scenic quality of the lakes for recreation use, and can make some boat ramps unusable. Gradual drafting during the October - March period is preferred over drafting from July through September. Drafting during the July-September period can have negative impacts on fish population productivity, while October-March drafting avoids these impacts.

Clear Creek Reservoir supports a good quality, diverse fish community, because reservoir water levels are fairly stable throughout the growing season, and because the reservoir topography provides an extensive shallow littoral zone. Stable reservoir levels, good access, scenic quality, and a high quality fishery also make Clear Creek Reservoir an attractive location for angling and boating. However, even small variations in reservoir levels can create significant changes in bank exposure because of the shallow areas near the edges of the reservoir. Division of Wildlife recently constructed a boat ramp extension to address this problem. All resources at this reservoir are best supported by a continuation of the current operation pattern, which minimizes water level fluctuations during the growing season.

Please see the charts on the following page for an overview of water level needs at Twin Lakes and Turquoise Reservoir. No chart is presented for Clear Creek Reservoir because typically there is not a significant fluctuation of water levels at that reservoir.

3. Pueblo Reservoir Water Level Preferences

Operations to satisfy water storage and water delivery needs are significantly different at Pueblo Reservoir than at Twin Lakes and Turquoise Reservoir. Instead of lowest reservoir levels in late winter and peak reservoir levels in July, Pueblo Reservoir typically reaches its lowest elevation in early November and its maximum elevation on approximately April 15. From April 15 to late October, the reservoir is gradually drafted. Recognition of these operational parameters, along with a longer growing season and year-round recreational use, produce different water level needs at Pueblo Reservoir. As a result, regardless of what plan of operations is implemented for Pueblo Reservoir, water level needs for various resources values will be in conflict during significant portions of the year.

November - Mid-April Boating and angling use are low during this period, and the riparian community is largely dormant. While the best water levels for the warm water fishery would be full as possible during this period, the fishery can survive if there is a sufficient pool of water during the fall and filling occurs during the winter.

Mid-April - October (Growing Season) Water level needs are in conflict during this period. The optimal water levels to support boating would be a full reservoir all season, but this conflicts with operational demands on the reservoir. Wildlife and riparian needs are best supported by a full reservoir on May 15, with slight drawdown starting any time between May 15 and July 15. A slight drawdown allows the rooting zones of riparian plants to remain in contact with groundwater levels, but allows exposure of the some reservoir substrate to grow annual vegetation species. The

Turquoise Reservoir/Twin Lakes
Summary of Water Needs for Resource Values

Month	Reference Points: 1982-1995 Reservoir Operations (mean surface elevation in feet)		Fisheries Needs	Boating Needs	Angling Needs	Wildlife & Riparian Needs	Other Needs
	Turquoise	Twin					
November	9860	9189	Full as possible (Send no more water down river than absolutely necessary)		Maintain level for ice fishing		Aesthetics same as fishing & boating
December	9855	9189					
January	9851	9188					
February	9845	9187					
March	9842	9186	Maintain water levels don't drop levels-filling is ok		Maintain water levels filling is ok		
April	9837	9186		High as possible minimal fluctuation			
May	9842	9186					
June	9864	9193	Don't drop res. elev. by a total of more than 10'		Don't drop res. elev. by total of more than 10'	Full reservoir by June	
July	9867	9193				Very limited drawdown is permissible, but maintaining full reservoir through August is optimal	
August	9867	9190					
September	9867	9190	Full as possible				
October	9863	9188					

Top of Conservation Pool

Turquoise Reservoir - 9,869.4 feet

Twin Lakes - 9,200.0 feet

Pueblo Reservoir
Summary of Water Needs for Resource Values

Month	Reference Points: 1982-1985 Reservoir Operations (mean surface elevation in feet)	Fisheries Needs	Boating Needs	Angling Needs	Wildlife & Riparian Needs	Other Needs
November	4850 Filling*	Full as possible				
December	4857					
January	4862					
February	4865					
March	4868				March and April filling reservoir is preferred	
April	Gradual drafting* 4865		As full as possible	For safety and shore access, maintain at least elevation 4860 to 4880.5. However anglers prefer high success rates, so biology needs must be strongly considered.		
May	4864	Maintain or fill			Reach full reservoir by May 15	For safety & shore access, maintain at least elevation 4860 to 4880.5
June	4864					
July	4858	Start rapid drawdown on July 15 to reduce surface area by 10% to 20% Maintain stable water levels from August 15 onward			June, July, August Slight drawdown is permissible	
August	4854					
September	4851					
October	4846					

* driven by water demand and weather

Top of Conservation Pool - 4,880.5 feet

warm water fish population is best supported by a full reservoir through July 15, followed by a rapid draw down between July 15 and August 15. The rapid drawdown allows colonization of the exposed substrate by annual species during the growing season, which contributes to reservoir food supplies when reservoir levels rise again. Given these conflicting demands, the overall resource preference is to prevent draw down as long as possible in the spring, within the confines of operational demands.

B. Summary of Natural Resource Water Preferences by Individual Resource Values

1. Water Preferences for Fish Populations

a. Arkansas River

The Arkansas River is noted for its exceptional brown trout fishery and for its developing rainbow trout fishery. Brown trout were the focus of this study because of their prevalence in the river, because the population is self-sustaining, and because any given operational program will influence rainbow trout in a similar manner. There are a number of non-game fish species present in the Arkansas River drainage, primarily found between Canon City and Pueblo Reservoir. This area was not extensively studied, but flows that protect and maintain game species should also protect non-game species. Rare species, such as greenback cutthroat trout, Arkansas River darter, and redbelly dace, are all found in the upper Arkansas River basin but have not been collected in the mainstem river or reservoirs. Habitat needs for brown trout and rainbow trout were analyzed using the Instream Flow Incremental Methodology (IFIM).

The two most important physical variables affecting fish habitat on the Arkansas River are velocity and depth. The further these variables are from the optimum value, the less likely that position is going to be occupied by a trout, because brown trout occupy positions in a stream that maximize net energy gain during foraging. The carrying capacity of a stream may be determined by available habitat and number of foraging sites.

Increasing flows frequently produce unfavorable habitat conditions in the Arkansas River, as illustrated in Appendix X.

Increasing velocity accounts for large drops in suitable habitat, particularly for small fish. For example, adult brown trout prefer a velocity of 1.3 feet per second for spawning, and velocities ranging from 0.9 to 1.3 per second for other activities, such as foraging. However, fry and juveniles prefer velocities of 0.3 to 0.7 feet per second. For all life stages, increased velocities not only increase the metabolic cost associated with foraging, but also create conditions that reduce the capture of drifting insects.

As with velocity, increasing depth accounts for drops in suitable habitat, especially for small fish. Depths of 2.0 to 3.0 feet are optimum for adult brown trout spawning, while the suitable range of depth for spawning is 4.8 to 36.0 inches. Redds are generally found at depths of 12.0 to 36.0 inches. However, juvenile brown trout have optimum habitat depths ranging from 0.9 to 1.7 feet. Finally, because brown trout are bottom-oriented, visual feeders, greater depth creates conditions that reduce the capture of drifting insects.

In coldwater environments, trout growth is a good indicator of the health of an aquatic ecosystem because it integrates all the biotic and abiotic variables impacting organisms and reflects secondary effects of chronic stress. Pre- and post-runoff periods (April-May and July-September) are critical for brown trout growth and survival, because there is a strong correlation between brown trout growth and discharge in the Arkansas River. Warmer water temperatures and poor prey availability make August and September particularly critical months for trout growth. The negative impacts from higher flows are not offset by releases of cooler water from Twin Lakes in August and September, because these releases will not decrease water temperature for any appreciable distance downstream.

To optimize the amount of available brown trout and rainbow trout habitat for all life stages on the Arkansas River from near Leadville to Pueblo

Reservoir, IFIM analysis showed that a year-round flow of 300 to 500 cfs should be maintained, measured at the Wellsville gauge. However, agencies that manage fish populations and fish habitat recognize that the spring runoff must be passed through the system. The most beneficial operation for the fish population would be to ramp down runoff flows as soon as possible, which creates a greater period of time when maximum habitat area is available to the fish population.

b. Turquoise Reservoir and Twin Lakes

Turquoise Reservoir and Twin Lakes are primarily managed for lake trout and rainbow trout. Both reservoirs are oligotrophic, meaning that they are low in plant nutrients and oxygen is typically distributed evenly throughout the water body. Lakes of this type are typically suited to salmonids, which are oxygen sensitive. Primary and secondary production is relatively low in both lakes, translating into limited food supplies for fish species. Highest production occurs in the warmer months of July and August in the euphotic zone, where there is sufficient penetration of sunlight into the water column to support plant growth. Thermal stratification at this time, coupled with major adjustments in water levels, increases flushing of nutrients from the reservoir. Maintaining lake levels and controlling flushing rates is critical for successful fishery management, particularly for lake trout. To foster maximum biotic production in these reservoirs and to protect and maximize littoral habitat during the summer months, water surface elevation should be held at some stable level.

Filling and maintaining water levels in Twin Lakes and Turquoise Reservoir as much as possible prior to October 1 ensures inundation of shorelines which provide spawning habitat for lake trout adults. Lake trout spawn during October and November in Twin Lakes. Although frequently not possible, maintenance or continued filling during the winter ensures eggs remain inundated until hatching and fry emergence in February or March. Stable water levels from March to June provides habitat for fry and juveniles until they move to deeper water by June. Adjustments to water levels from June to August of more than 10 feet from full pool decrease primary and secondary production. Maintaining stable water levels from August to October lends stability to the reservoir, further enhancing productivity.

c. Clear Creek Reservoir

Management for kokanee salmon and rainbow trout are emphasized in Clear Creek Reservoir. Clear Creek Reservoir is the most productive of the three upper basin impoundments, however, it is still considered oligotrophic. Clear Creek Reservoir does not experience daily adjustments to its water level that Twin Lakes and Turquoise Reservoir do. As a result, Clear Creek Reservoir shows better survival and growth rates, including overwintering, of key species. Fish population needs are best met if Clear Creek Reservoir is maintained as full as possible on a year round basis.

d. Pueblo Reservoir

Pueblo Reservoir is managed as a warm, cool and coldwater fishery. The coldwater fishery consists mainly of rainbow trout maintained by annual stocking. The warm and cool water fishery is comprised primarily of black basses, crappie, bluegill, walleye, wipers, and channel catfish. Walleye, wipers, and channel catfish are stocked, while bass and crappie are not stocked.

At times the fluctuation of water levels in Pueblo Reservoir has been very severe. Major draw downs have dropped the water level up to 49 feet below conservation pool. Depending on when these occur, they can have a major effect on the production of sport and forage fish.

Gradually filling Pueblo Reservoir from November through March allows for the inundation of vegetation and shoreline which will provide food, cover, and spawning areas in the spring. A full reservoir from March to mid-July allows for good spawning habitat, high plankton levels to feed fry, as well as cover for adults, juveniles, and fry. Rapidly drawing the reservoir down from mid-July to mid August exposes shoreline for recolonization of annual (non-riparian) vegetation and concentrates forage species for maximum utilization by sport species for growth.

Maintaining stable water levels from mid August to November lends stability to the reservoir, further enhancing productivity.

2. Water Preferences For Riparian Habitats

a. Arkansas River

Riparian and wetland resources in the study reach are largely modified. A century of road and railway construction, dams, irrigation development, conversion of land to agriculture, residential development, and other modifications have influenced the riparian resources present today. Modifications are generally centered around:

- Vegetation manipulation -- land use activities such as recreation and grazing, introduction and invasion of exotic vegetation, selective harvesting of certain riparian species, etc.
- Watershed alteration -- land use activities such as roads, logging, agriculture, mining, and urbanization that affect factors such as infiltration, runoff, sediment supply, and water quality.
- Direct modification -- channelization, draining, filling, conversion to other uses, etc.
- Hydrology alteration - water diversions, water importations, storage, etc.

Capability and potential of most riparian and wetland resources within the study area is determined a great deal by the natural shape and form of the river corridor that is created by geology of the area. Much of the Arkansas River is bounded by rock, is narrow, and confined due to the deep canyon landform. Many reaches which were confined naturally are now even more confined because of railway and highway construction. The canyon setting, coupled with high flows, limits soil development and plant rooting abilities. However, some reaches are less confined, and have meander bars and streamside margins with a limited band of riparian vegetation. Downstream of Canon City, and the short reach between Leadville and Granite, have well-developed floodplains with substantial riparian and wetland vegetation. The majority of the riparian and wetland vegetation is composed of grasses-sedge-rush, willows (several species), alders, birch, and cottonwood.

Rather than quantifying the exact changes to be expected from flow alterations, the focus of this water needs assessment was to review the literature related to riparian communities and identify general relationships and effects that river managers should keep in mind while managing flows. Determining the exact impact of either or large or small scale flow alterations on Arkansas River riparian communities would require an exhaustive, long-term study that is beyond the scope of the present Water Needs Assessment.

The unique setting of each riparian area along the river, in terms of geomorphology, groundwater levels, and gaining/losing stream reaches, also makes it difficult to predict the effects of flow modification without intensive local study. For example, in the Brown's Canyon reach, each 100 cfs increase in flows increases the water surface elevation by 3% to 5%, while in the Floodplain site, the increased water surface elevation is less because of the broader channel. However, the impact from a 100 cfs increase in flows on vegetation will be greater in the Floodplain site, because the vegetation line at Floodplain is closer in elevation to the mean annual water surface elevation.

There are three factors which are the most critical in maintenance of riparian habitats: (l) maintaining the historic frequency and duration of floods, (2) maintaining growing season groundwater levels in areas adjacent to the stream, and (3) maintaining the annual and seasonal variation in the hydrograph.

The riparian community is a product of the long-term hydrology of the river, so fairly large variations in flow for one year will likely not have a significant effect. Consistently higher or lower flows, however, will likely alter the extent and location of riparian vegetation. The outcome of flow manipulation is more likely to be the evolution of a new riparian area which is a different width and elevation, rather than elimination, enhancement, or large changes in the overall acreage of the riparian community.

For example, a consistent increase in growing season base flows will likely alter the channel width in some reaches by inundating plant communities and by erosion of fine sediments which provide growing mediums for riparian species. In addition, stream banks may experience catastrophic blow-outs as the river attempts to adjust its channel to the new hydrology.

Conversely, consistently lower base flows during growing season will allow the encroachment of vegetation into channel margins. The lower water table associated with lower base flows may place water beyond the reach of the root zone of some established plants. The riparian area may experience a decrease in basal area, density, and width. However, the lower flow may allow colonization of areas that were previously inundated and could not support riparian vegetation.

Finally, alteration of the annual and seasonal variability in flows can eliminate processes that are essential to the survival and evolution of riparian zones. Periodic low flow episodes allow plants to become established in areas where they will later trap and retain sediment. Scouring associated with high flow events creates habitat areas where early successional plants can become established.

b. Reservoirs

Maintaining the historic pattern of operations at Turquoise Reservoir and Twin Lakes will maintain the plant communities which evolved under those conditions. Any drawdowns which occur more quickly than the historic pattern will likely limit and/or modify wetland and riparian potential at these reservoirs.

Pueblo Reservoir operations do not currently favor wetland and riparian vegetation because of the timing and magnitude of drawdowns. Accelerating the delivery of water from the upper reservoirs to Pueblo in order to maintain a fuller pool during the growing season would be unlikely to enhance the wetland resource at Pueblo. The quantity of water required to enhance Pueblo Reservoir's riparian values is much larger than is available for delivery from upper reservoirs. Similarly, maintenance of a pool level which enhances riparian/wetland values would require operational changes that are presently outside of the reservoir's operating principles.

3. Water Preferences For Terrestrial Wildlife

a. Arkansas River

The wildlife values associated with the Arkansas River corridor and its riparian habitats, wetland habitats, floodplains, and reservoirs are diverse and important in maintaining the ecological stability of this part of Colorado. Riparian and wetland areas have been well documented as the most productive and attractive of all wildlife habitats. Accordingly, riparian areas often provide the key resources that support biological diversity both in the riparian and in nearby uplands. Terrestrial wildlife habitat functions provided by the Arkansas River include migration and dispersal routes, and a forested connector between habitats for wildlife such as birds, bats, deer, elk and small mammals.

In general, flow regimes which support a stable riparian community will also support the most stable and diverse assemblage of terrestrial wildlife. As mentioned in the riparian discussion three factors are the most critical in maintenance of riparian habitats: (1) maintaining the historic frequency and duration of floods, and (2) maintaining growing season groundwater levels in areas adjacent to the stream, and (3) maintaining the annual and seasonal variation in the hydrograph.

Periodic flooding is required to maintain the species composition of the riparian plant community because this composition is based upon the tolerance of each species to frequency and duration of flooding. Flooding is also required to deposit sediments on which the riparian community can establish, and flooding provides nutrients for established riparian communities. High flows also provide temporary side channel and backwater habitats that are critical to some species. The scouring action provided by flooding also provides the unvegetated soil and substrates needed in the life stages of some bird and small mammal species. On the other hand, severe flooding of several weeks (sustained flows that are larger and

last longer than the average annual high flow on the river) temporarily eliminates and may limit resident small mammal populations in the floodplain.

Almost all wildlife species are negatively impacted by unexpected, sustained, and large changes in flows that come at critical points in wildlife life cycles. For example, birds that nest on sand and gravel bars during early spring can be disrupted by unexpected increase in flow that are large enough to inundate these habitats. Fish that spawn in backwater areas can be severely impacted by flows which are not high enough to inundate these areas during spawning periods. While many natural events, such as thunderstorms and rain-on-snow events, can drastically change flows, they are typically of a short duration and provide the type of flood disturbance that can be beneficial for wildlife species. Conversely, reservoir releases that produce flows outside the historic range of flows for extended periods of time can disrupt critical life stages of wildlife species. The species and life stages that are impacted depend upon the exact timing and magnitude of the reservoir releases.

Flow-dependent phenomena that can negatively impact waterfowl include damage to nests from dramatic water level fluctuations, removal or inundation of food sources by severe flooding, and desiccation of water-dependent insects and vegetation that serve as food sources when flow is reduced. Certain species, such as wood ducks, require flooded woodland areas for a portion of the year, and flow regime that removed peak flows that create these areas would be detrimental.

For raptors, the continued viability of riverine cottonwood-willow riparian sites is extremely important, because they provide roosting and nesting sites. A viable fish population is critical to raptors as a food source, and flow fluctuations that drive small mammal prey species from the riparian corridor would be detrimental.

Similarly, some shorebird species, such as blue herons, rely upon viable riverine cottonwood-willow riparian areas. Shorebird species are even more sensitive to flow variations and flooding of riparian areas, because they are dependent on areas such as mud flats, shallows, and gravel bars for feeding purposes. Some shorebird species, such as avocets, also nest in these habitats, so unexpected flood events can severely impact their populations.

The spring and summer breeding period of amphibians and reptiles makes them especially vulnerable to dramatic changes in river flow that affect sidewaters and backwaters. For examples, reptiles and amphibians can be negatively impact by reservoir releases of excessively cold water that invade sidewaters and backwaters, because they will not feed or breed in water temperatures of less than 50 degrees.

b. Reservoirs

Wildlife management agencies recognize that reservoirs are not constructed to support optimal wildlife values. However, long term operations have been somewhat consistent, so certain wildlife species have adapted to and use the habitats surrounding the impoundments. Accordingly, significant modification of reservoir operations away from historic practices that could impact these habitats will, in turn, have an impact on wildlife populations. At Pueblo Reservoir, maintaining a full pool for a longer period of time during the growing season, would benefit riparian values, which would, in turn, benefit wildlife populations. However, maintaining a full pool for a longer time during the growing season could be negative for the fish population, and many wildlife species depend on the fish population as a food source. Finally, the basin-wide impact of reservoir levels must be considered. If large releases are required from the upper reservoirs to maintain Pueblo water levels, the negative effects on Turquoise Reservoir and Twin Lakes wildlife populations may outweigh the gains at Pueblo Reservoir.

4. Water Preferences for Recreation

a. Arkansas River

The upper Arkansas River is the most intensively used river in the United States for whitewater

boating. Based on BLM/USFS/Colorado State Parks records, 1996 recreation use on the river was 590,192 user days, an increase of 75% over 1990 use levels.

This report focuses primarily on two of those activities, fishing and boating use. Of the 590,092 river use total, 287,000 user days were reported for boating, and between 30,775 user days (Division of Parks and Outdoor Recreation estimate) and 64,614 user days (Division of Wildlife estimate) were reported for angling.

Approximately 95% of the total boating use is comprised of rafting, including both commercially organized trips and privately-organized trips. Each raft carries an average of seven persons. Approximately 5% of the total is comprised of kayaking use, with an average of one person per kayak. During the July 24 September 7 period there is an average of 2,934 boaters per day.

Of the river angling days, about 54% is flyfishing use, 41% is spincasting use, and about 5% is float-fishing use. During the July 24 to September 7 period, there is an average of approximately 244 fisherman per day using the Arkansas. This figure is derived by averaging statistics from the Division of Parks and Outdoor Recreation estimate, which estimates 158 fishermen per day, and the Division of Wildlife, which estimates 331 fisherman per day.

The recreation work group and its consultant, EDAW, Inc. analyzed user preferences for water levels using various user surveys. Users in both boating and angling recreation activities were asked to judge the acceptability of various flow levels for their respective activities. The following table shows the optimum flow preferences by each type of recreational user.

b. Turquoise Reservoir and Twin Lakes

Twin Lakes Reservoir and Turquoise Lake Reservoir reported 26,562 user days and 49,610 user days respectively, in 1996.

Survey results indicate that users prefer higher lake levels. However, changes in reservoir levels do not appear to have a pronounced effect on recreation activities and opportunities. Regardless of the given reservoir level, a vast majority of the users indicated that they would return to the site again under identical conditions. These results suggest that while reservoir water levels do influence the overall quality of the recreation experience, they do not play a significant role in determining user behavior patterns for either boating or fishing activities.

c. Pueblo Reservoir

Lake Pueblo State Park, with more than 1,543,000 visitors in 1996, was the fifth most visited recreation area in Colorado. This figure is an increase of 41% over 1990 use levels.

Survey results indicate that users prefer higher lake levels. Recreation users at Pueblo Reservoir indicated that they were more strongly affected by water levels than users at Turquoise or Twin Lakes. A majority of users expressed that their quality of recreation experience was negatively affected at lower lake levels, especially scenic quality. However, changes is reservoir levels do not appear to have a pronounced effect on user behavior patterns. This may be in part due to the fact that Pueblo Reservoir users were, and typically are, exposed to much greater drawdowns than users at Turquoise Reservoir or Twin Lakes. Conditions at Pueblo Reservoir were reported to improve considerably with regard to safety, shoreline access, and visual quality a elevations above 4850 feet.

Recreation Activity	Optimum Flow Range	Median Optimum Flow
Fly Fishing	400 - 500 cfs	450 cfs
Spin Fishing	700 - 1200 cfs	950 cfs
Float Fishing	900 - 1200 cfs	1050 cfs
Kayaking	1300 - 1500 cfs	1400 cfs
Rafting	1500 - 2000 cfs	1750 cfs

Source: Page 4-1, EDAW Arkansas River Study, October 28, 1997

The amount angling use at Pueblo Reservoir is also dependent on the quality of fish populations being sought, in terms of size and number of fish. Therefore, fishing recreation can also be correlated with water levels that provide preferred water elevations for production of warm water fish species. However, reservoir elevations that promote productivity within the fish population are typically in conflict with preferred elevations for boating. Given this conflict, it appears that anglers will prefer conditions which provide safety, shoreline access, and. visual quality, as long as the fish population provides satisfactory catch results, in terms of size and numbers.